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Published in:
Conference proceedings

Publication date:
2010

Document Version
Publisher's PDF, also known as Version of record

Frequency modeling of wind power fluctuation and the application on power systems

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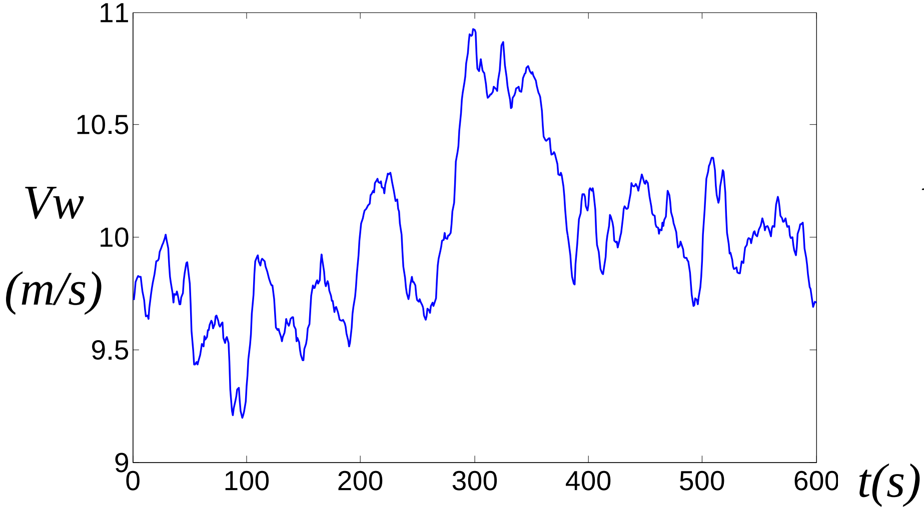
Outline

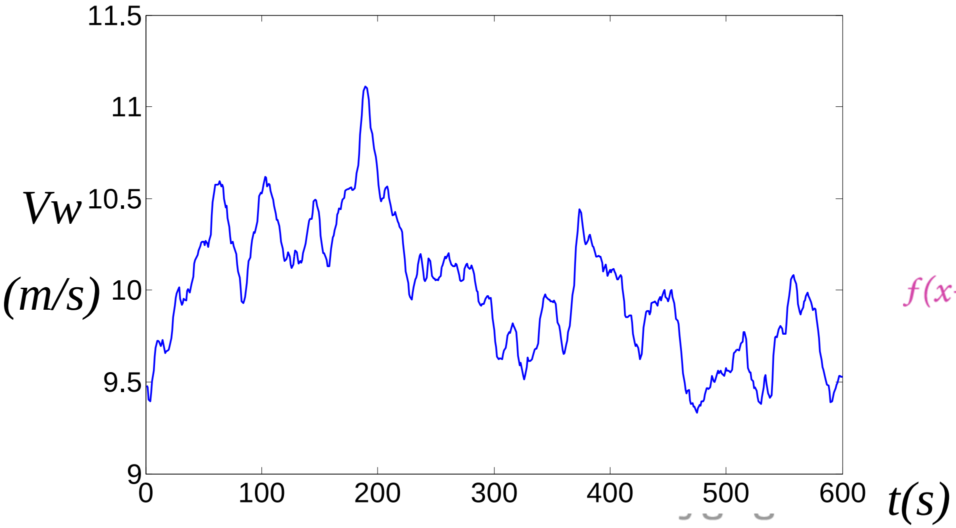
- Introduction
- Frequency modeling of wind power
- The application in power system
- Conclusion

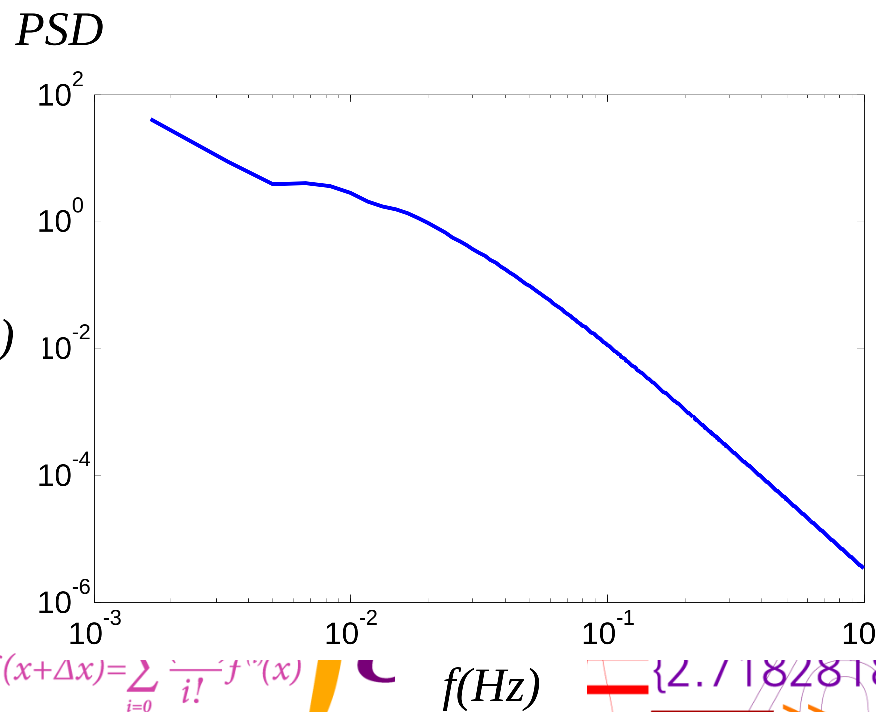
Introduction

- The penetration of wind power is rapidly growing
- Power fluctuation is a nature characteristic of wind power
- Especially a concentrated wind farm may bring more fluctuation injection
- Balance Grid V.S. Fluctuated Wind

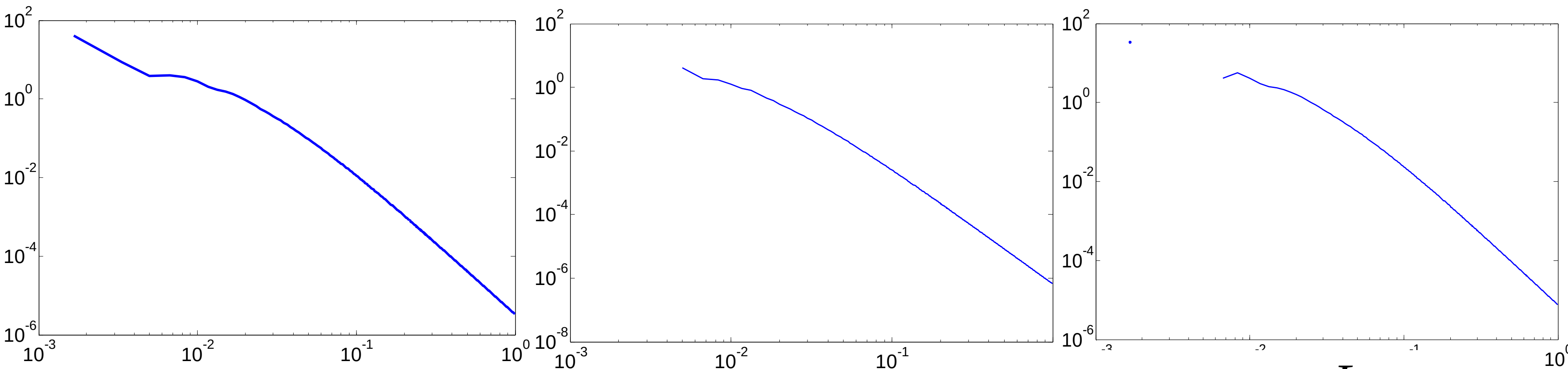
Frequency modeling of wind







Frequency modeling of wind

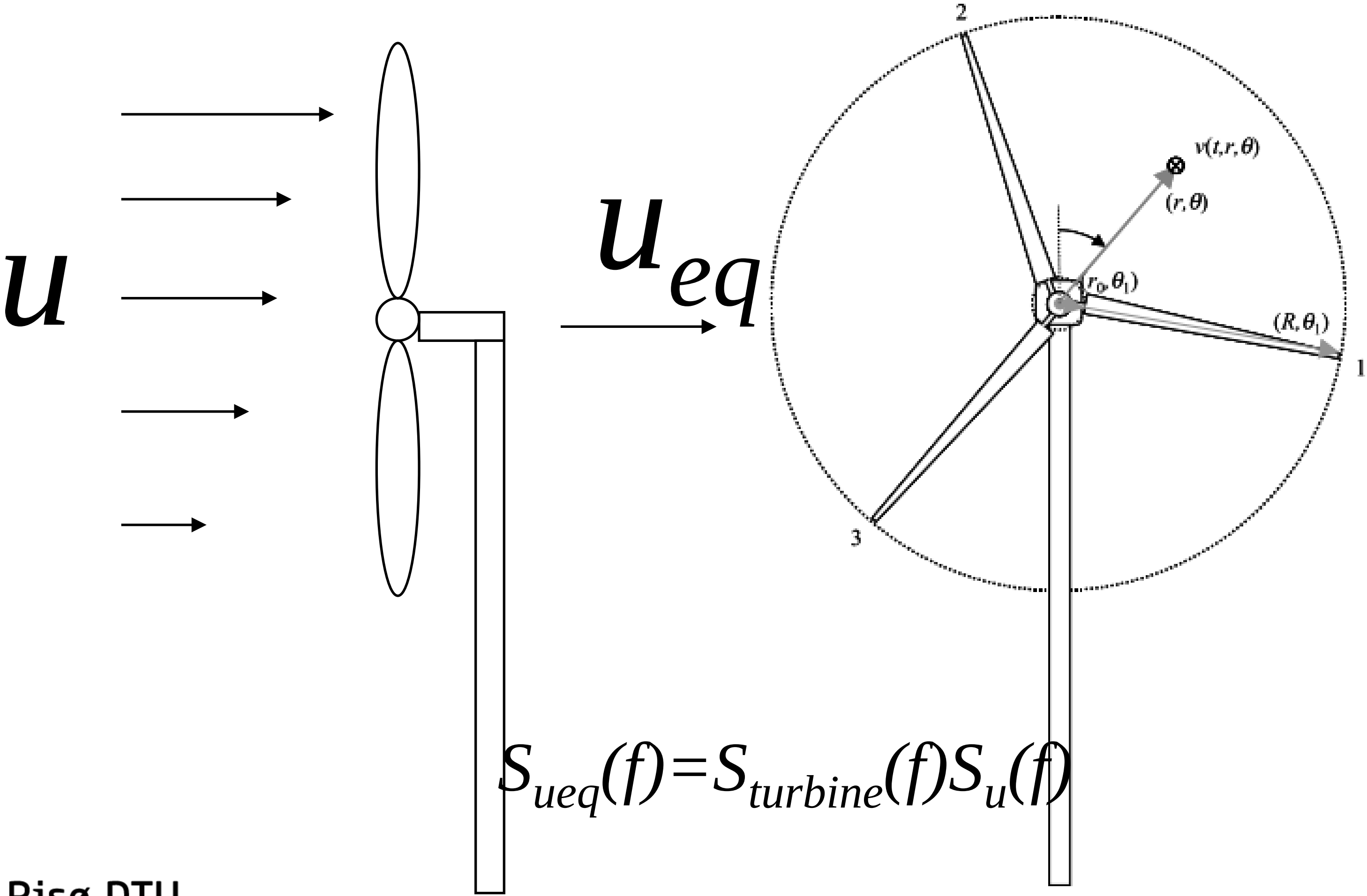


$$S_{LF}(f) = (\alpha_{LF} V_0 + \beta_{LF})^2 \frac{\frac{z}{V_0}}{\left(\frac{zf}{V_0}\right)^{5/3}\left(1+100\frac{zf}{V_0}\right)}$$

$$S_{IEC}(f) = \sigma^2 \frac{2\frac{L_1}{V_0}}{\left(1+6\frac{L_1}{V_0}f\right)^{5/3}}$$

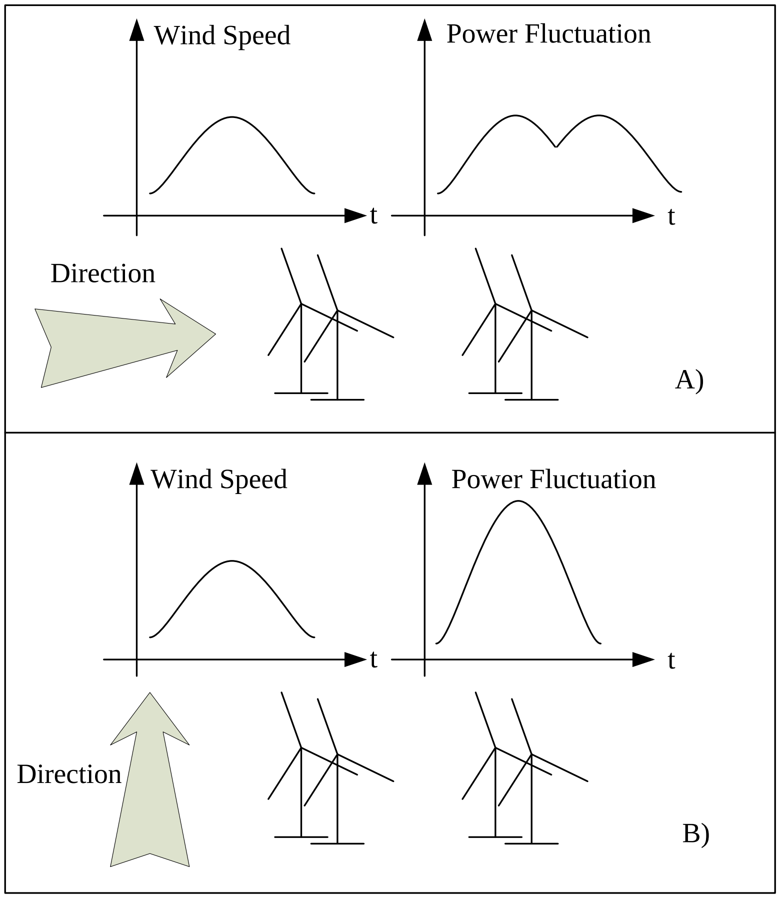
$$S_u(f) = S_{IEC}(f) + S_{LF}(f)$$

Equivalent wind passing through wind turbine



$$S_{ueq}(f)=S_{turbine}(f)S_u(f)$$

Coherence matrix of wind farm



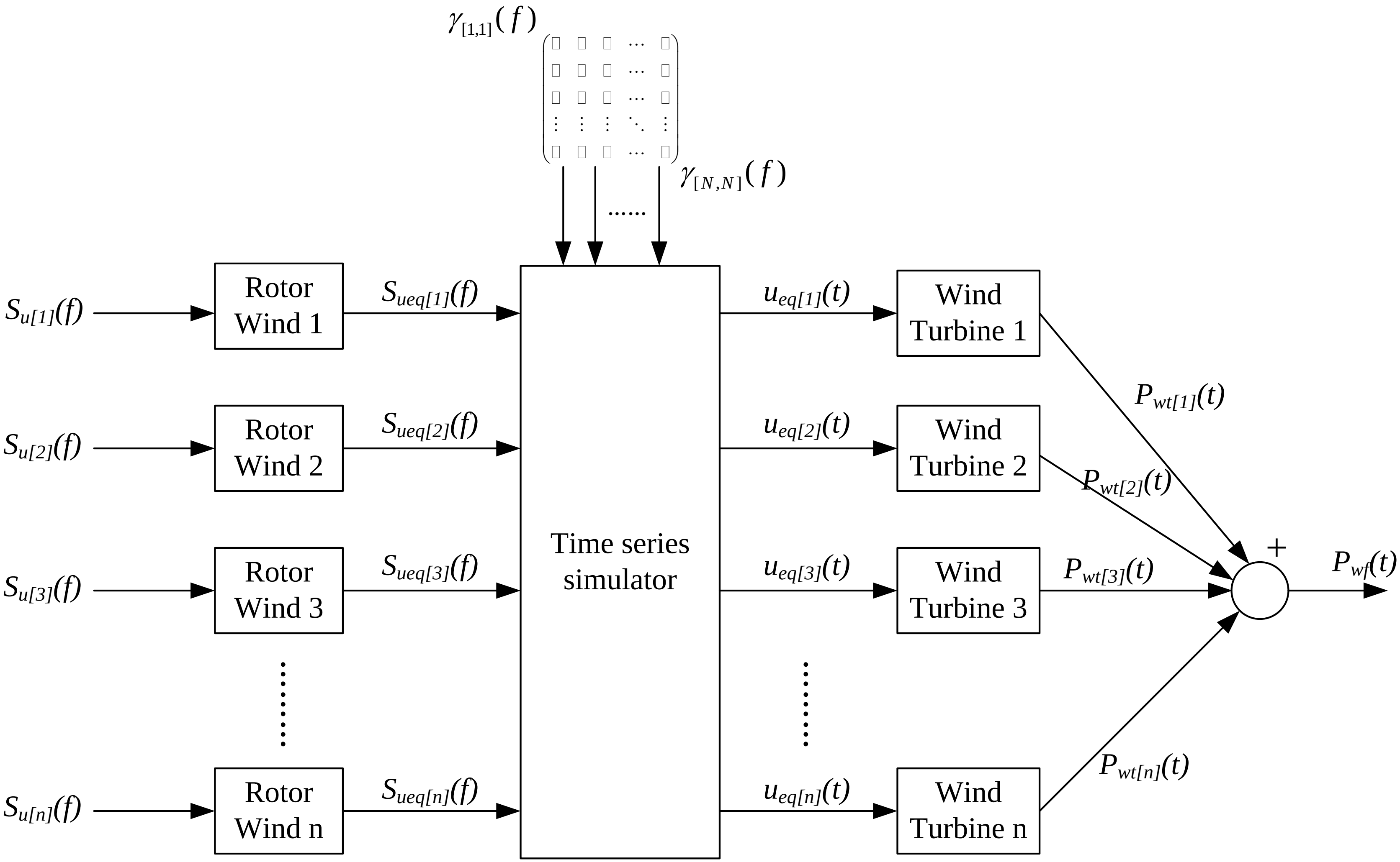
$$\gamma_{[1,1]}(f)$$

$$\begin{pmatrix} \square & \square & \square & \cdots & \square \\ \square & \square & \square & \cdots & \square \\ \square & \square & \square & \cdots & \square \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \square & \square & \square & \cdots & \square \end{pmatrix}$$

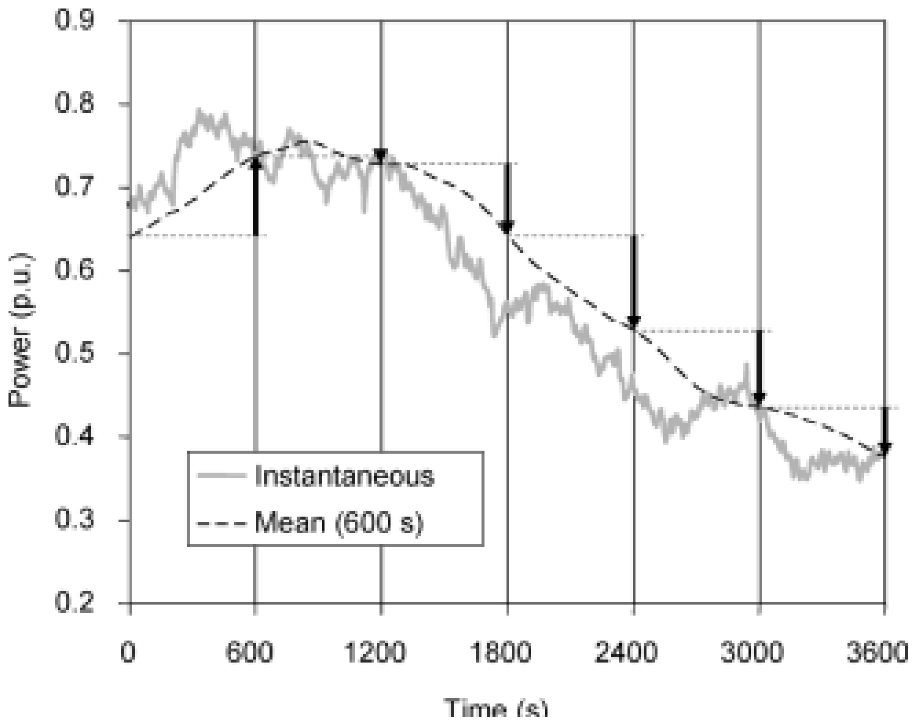
$$\gamma_{[N,N]}(f)$$

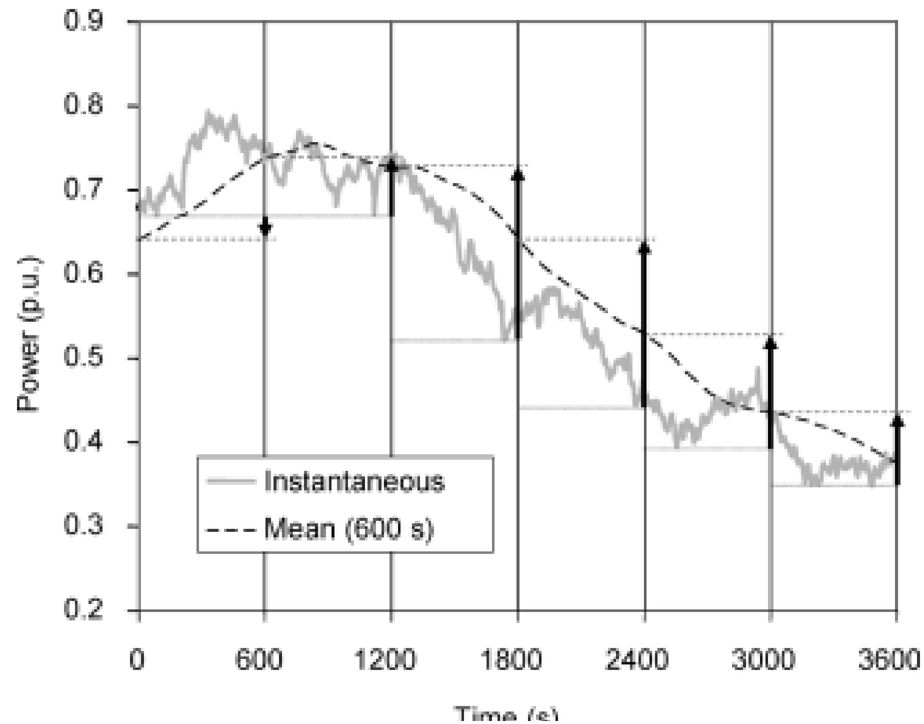
Wind Speed Coherence

Frequency modeling of wind power fluctuation



Normal weather condition — ramp and reserve

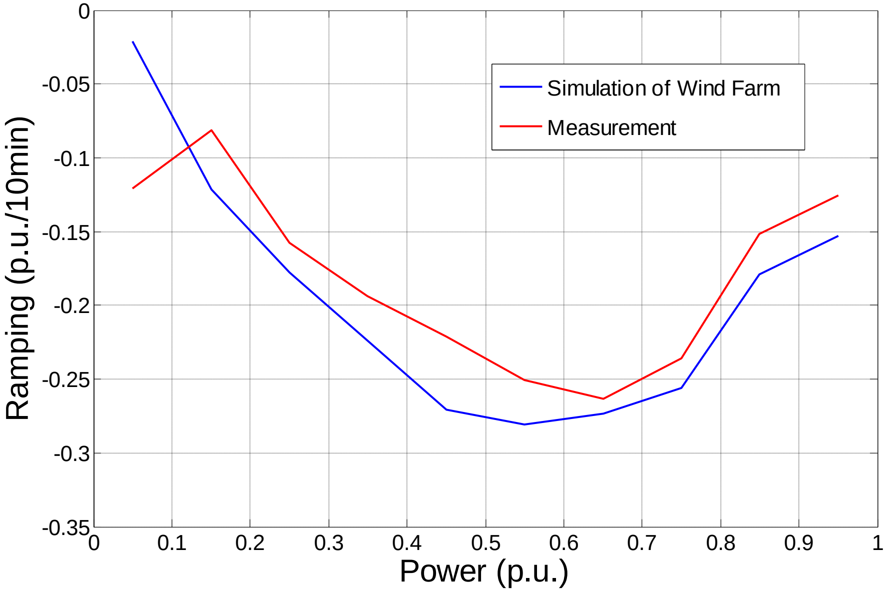


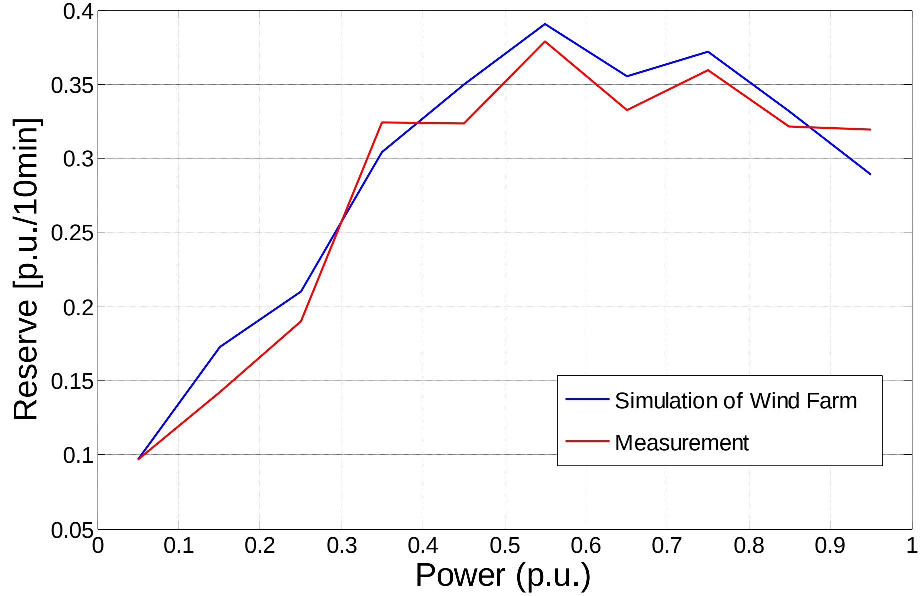


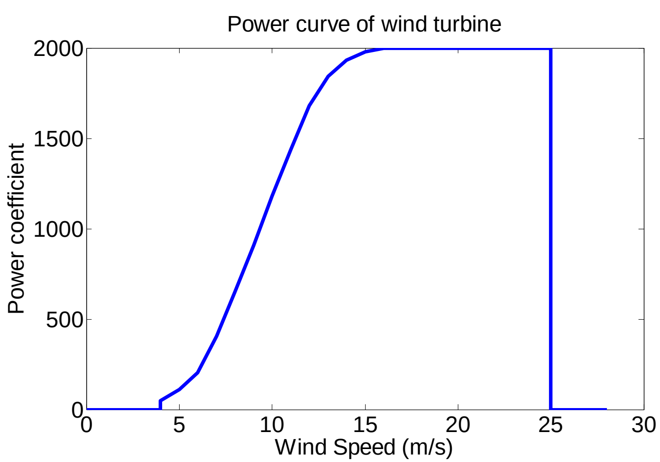
$$P_{ramp}(n)=P_{mean}(n+1)-P_{mean}(n)$$

$$P_{res}(n)=P_{mean}(n)-P_{min}(n+1)$$

Normal weather condition – ramp and reserve

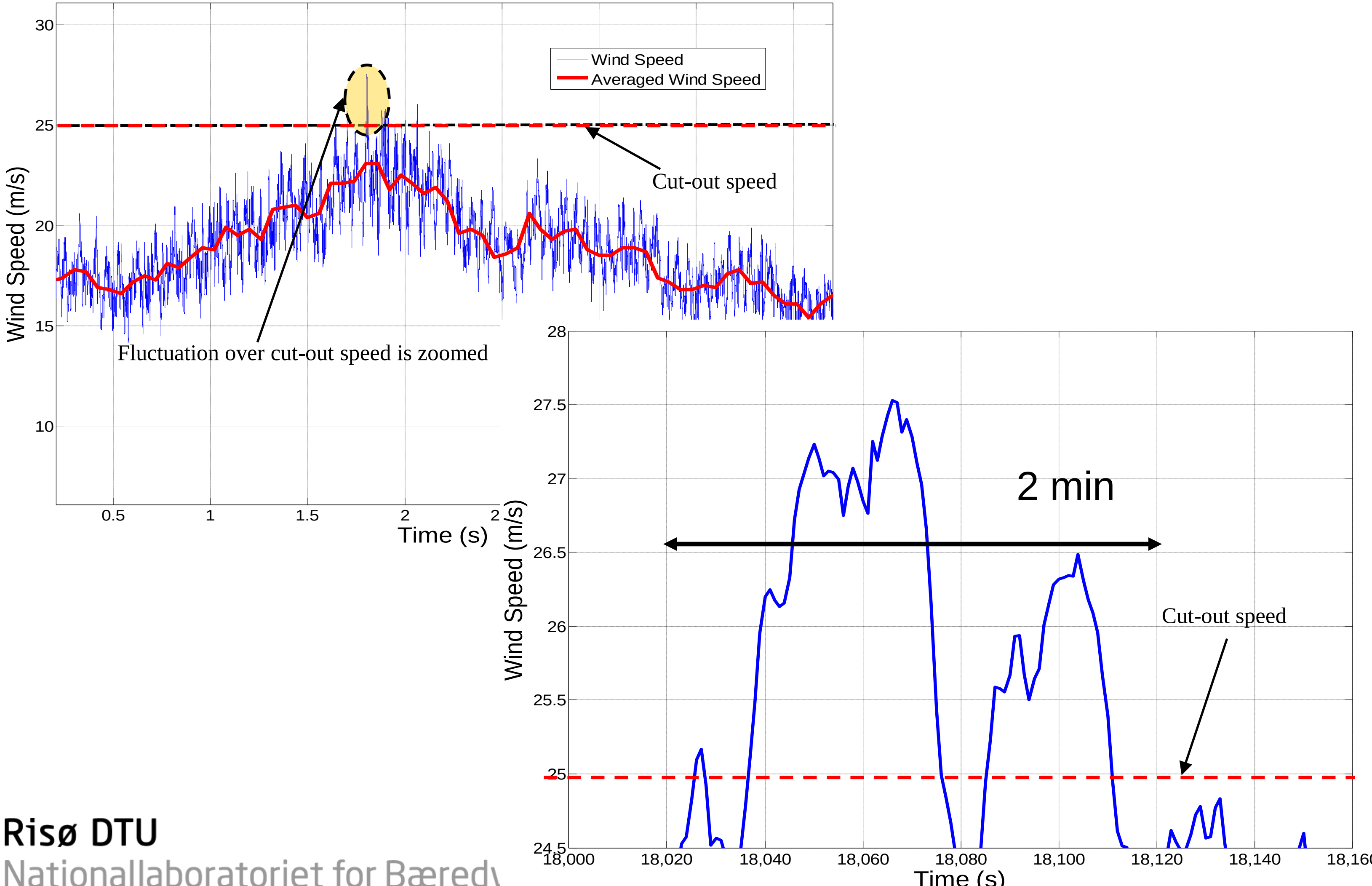




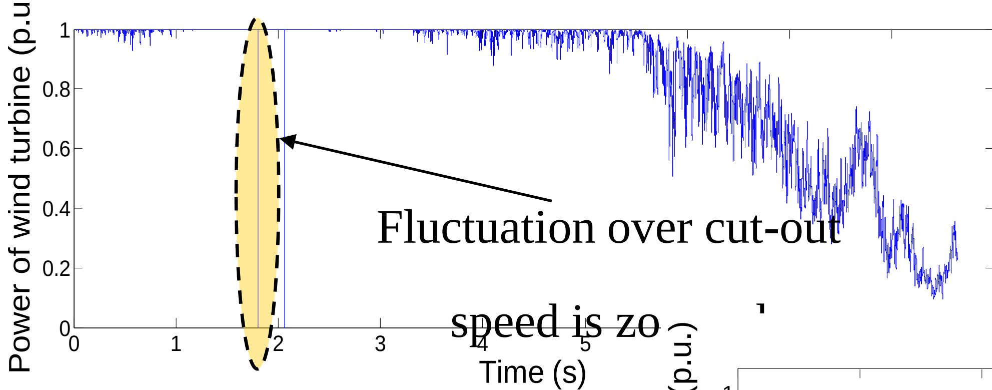


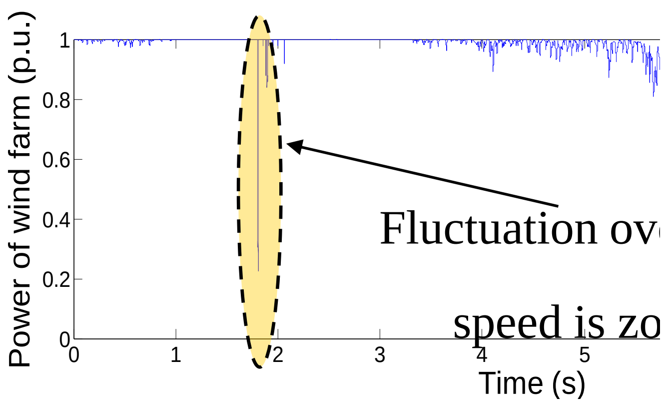
Power fluctuation is sustained near rated power because of the power controller

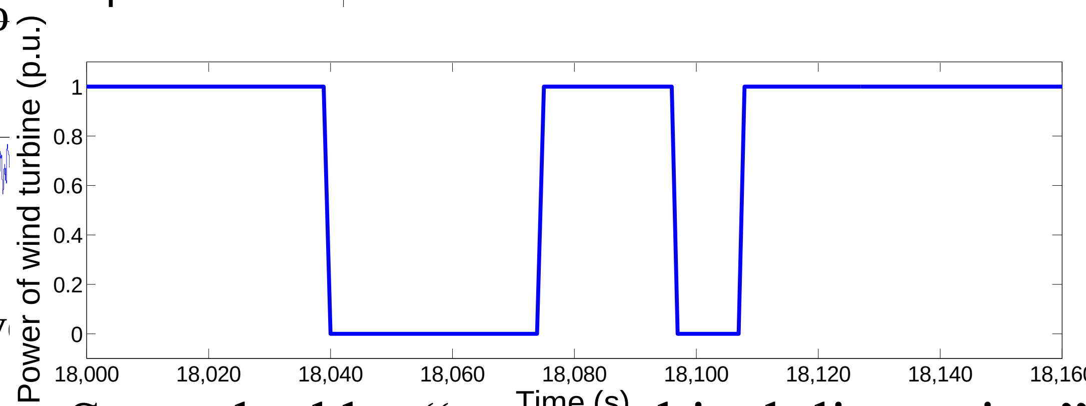
Extreme weather condition



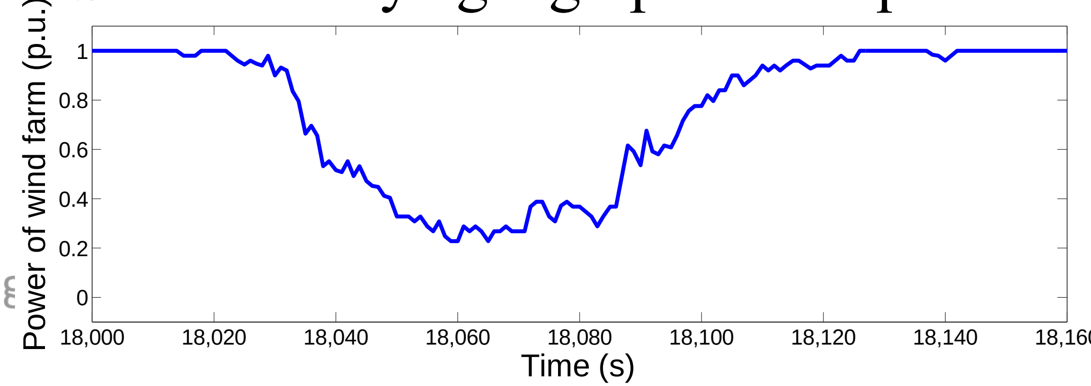
Extreme weather condition







Smoothed by “geographical dispersion”

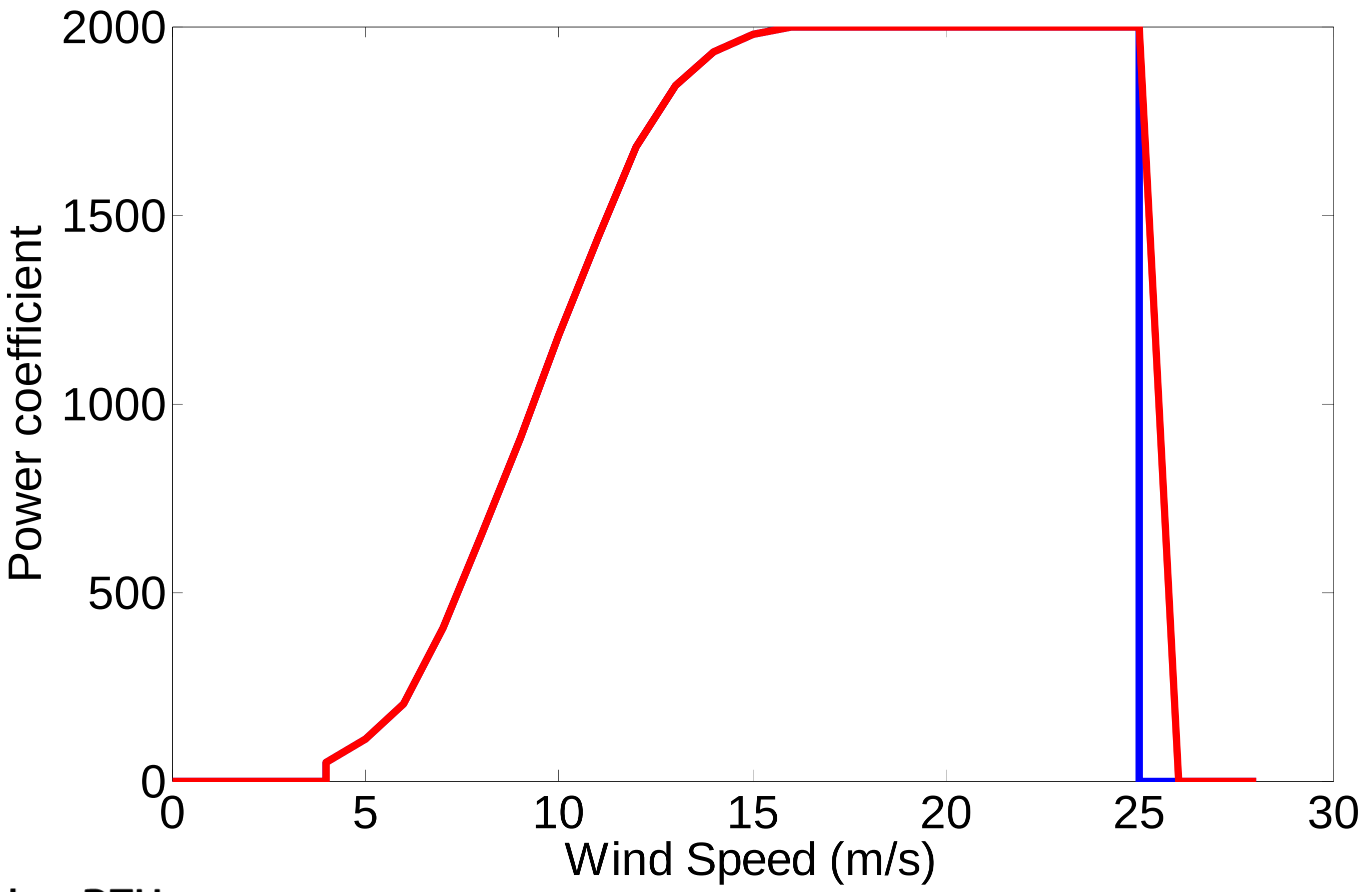


Conclusion

- Frequency model provides an unified way to describe the wind power fluctuation
- Simulation length can be hour to hour and resolution can be second to second
- Under normal condition, highest fluctuation risk happens when the wind farm is producing 0.7-0.9 p. u.
- Under extreme condition, “geographical dispersion” is simulated, which smoothes the power drop when a storm hits.
- In future, this model is extended to assess the frequency deviation risk and the smooth strategy design.

Thank you!

Extreme weather condition



Ramp and Reserve